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Transgenic mice carrying an activated form of the N-*ras* oncogene under the control of the Mammary Tumor Virus Long Terminal Repeat promoter develop mammary carcinomas with a high frequency during the first few months of their life. The α6β4 and, to a minor extent, the α2β1 integrin were found to be upregulated and diffusely distributed at the tumor cell surface in the primary lesions of these mice. These events were accompanied by a loss of laminin staining indicative of defective basement membrane deposition. The α3β1 integrin was diffusely distributed, but not upregulated. Since transfection of N-ras into cultured murine breast epithelial cells did not produce the changes in integrin expression detected *in vivo*, it is likely that these changes occur as a result of tumor progression independently of a direct action of N-ras. We have discovered that the activated EGF-R combines sequentially with fyn and α6β4, leading to disassembly of hemidesmosomes and increased migratory activity. Future experiments will be addressed at determining if the EGF-R family member Erb2, which is often mutated and overexpressed in breast cancer, also combines with α6β4 and if this event contributes to breast cancer progression.

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Principal Investigator's Signature

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INTRODUCTION

Cell-matrix interactions are likely to play an important role in breast tumorigenesis. Most human breast cancers arise from the transformation of ductal epithelial cells (1-3). Normal ductal epithelial cells rest on a basement membrane, to which they adhere tightly (2). The adhesion of normal breast epithelial cells to the basement membrane is thought to be important for the organization of the cytoskeleton and the consequent establishment of polarity. In addition, recent results indicate that normal breast epithelial cells receive signals from the basement membrane and these signals help them maintain a differentiated phenotype (4). When compared to normal cells, breast carcinoma cells show a defective interaction with the basement membrane. First, like most carcinoma cells, they fail to assemble basement membrane components in an organized extracellular matrix, both *in vivo* and *in vitro* (5, 6), and show cytoskeletal defects (7). Second, in contrast to normal breast epithelial cells, carcinoma cells do not arrest their growth when placed in a reconstituted basement membrane gel (6). It is important to understand the molecular basis of these phenomena because they are likely to contribute to the ability of breast carcinoma cells to detach from the original tumor and invade adjacent tissues.

The molecular characterization of integrins provides a unique opportunity to examine the role of cell-matrix interactions in breast cancer. The integrins are a large family of adhesion receptors which bind to extracellular matrix components and, in some cases, to counter-receptors on other cells (8). They consist of two distinct membrane-spanning subunits, α and β. At present we know of at least 9 homologous β subunits and 15 α subunits which can combine to form 21 receptors with distinct ligand binding specificities. Both the α and the β subunit (each ca. 140-200 kD m.w.) have a large extracellular portion, a transmembrane segment, and a short cytoplasmic domain. A notable exception is the $\beta 4$ subunit that has a large cytoplasmic domain. While the extracellular N-termini of α and β subunits associate to form the ligand binding pocket, the cytoplasmic domains of integrins interact with intracellular molecules.

The binding of integrins to extracellular matrix components promotes cell adhesion or migration, but ligation of integrins also results in intracellular signals which influence proliferation and differentiation (9). While contact with extracellular matrix components is required for the progression of normal cells through the cell cycle, a phenomenon called anchorage dependence, strong adhesion to an organized extracellular matrix seems to be able to limit cell proliferation (10) and promote differentiation (4). The ability of integrins to modulate gene expression may help to explain the effects that the extracellular matrix has on proliferation and differentiation. The mechanisms by which integrins affect gene regulation are not completely understood, but likely depend on the ability of the cytoplasmic domains of integrins to interact both with the cytoskeleton (11) and with signaling molecules, such as the adaptor protein Shc (12, 13) and Focal Adhesion Kinase (FAK) (14).

Neoplastic cells are characterized by a number of adhesion abnormalities which may explain their ability to grow independently of the positive and negative control signals originating from the extracellular matrix (15). Virally transformed fibroblasts have a more rounded morphology in culture than their non-transformed counterparts. In addition, they often lack a cell surface fibronectin-containing pericellular matrix (16). The defective fibronectin matrix of transformed fibroblasts may only partially be attributed to either decreased biosynthesis or increased proteolytic degradation of fibronectin, since the fibronectin secreted by transformed cells is regularly incorporated in the extracellular matrix by normal cells (17). This suggests that transformed cells can not retain at their surface the fibronectin they produce, perhaps because of a defect in the integrin receptors. Several observations indicate that the expression and function of integrins are altered in neoplastic fibroblasts. While in normal fibroblasts the β1 integrins, which include the α5β1 fibronectin receptor, are clustered in focal adhesions (18-20), transformed fibroblasts lack such structures and their β1 integrins are found diffusely distributed over the cell surface (20, 21). In addition, in fibroblasts transformed by tyrosine kinase oncogenes the β1 subunit is found to be partially phosphorylated on a tyrosine residue (22), a phenomenon which may reduce its ability to interact with the cytoskeleton (23). Finally, the expression of α5β1 and of another β1 integrin, probably α1β1, is suppressed in fibroblasts transformed by oncogenic viruses (24).

We have tested the hypothesis that changes in the level of expression or function of the α5β1 fibronectin receptor contribute to the adhesive abnormalities of transformed fibroblasts by overexpressing this integrin in Chinese hamster ovary (CHO) cells (12). The CHO cells have a transformed morphology, deposit little fibronectin in their pericellular matrix and are tumorigenic in vivo. As a result of the α5β1 overexpression, the CHO cells accumulated a fibronectin matrix and became less migratory. These results indicate an inverse correlation between matrix assembly of fibronectin and cell migration and suggest that the loss of fibronectin matrix and the increased invasive ability of transformed fibroblasts can be both brought about by a reduced expression or function of α5β1. Interestingly, the CHO cells overexpressing α5β1 were also found to be more anchorage dependent than the controls and were not able to form subcutaneous tumors in nude mice. K562 leukemia cells selected for high level expression of α5β1 show a similar normalization of growth properties (25). Conversely, CHO cells selected for their low levels of α5β1 expression are more tumorigenic than unselected cells (26). Thus, it appears that changes in the level of expression or activity of certain integrins may not only be responsible for the adhesive defects of neoplastic cells but may also contribute to their unregulated growth. Taken together, these observations suggest that the role of integrins in tumorigenesis is twofold: first, integrins mediate stable adhesion or migration onto extracellular matrix components and changes in their level of expression and function may, therefore, contribute to tumor invasion. Second, integrins transmit signals from the extracellular matrix to the cell interior and these signals affect cellular growth and

differentiation. Therefore changes in integrins may contribute to the unrestrained growth and lack of differentiation of neoplastic cells.

Although the adhesive phenotype of breast carcinoma cells is less well known than that of neoplastic fibroblasts, certain rules learned from the analysis of virally transformed fibroblasts seem to also apply to these cells. For example, breast carcinoma cells fail to assemble basement membrane components in an organized extracellular matrix (5, 6) and show enhanced ability to grow when confronted with a reconstituted basement membrane gel (6). Immunohistochemical studies have indicated that the expression levels of the α2β1 collagen/laminin receptor, the α5β1 fibronectin receptor and the α6β4 integrin are altered in human carcinomas of the breast (27-29). In addition, while integrins are generally polarized at the basal or baso-lateral surface in normal breast epithelium, the integrins expressed in breast carcinoma cells are diffusely distributed over the cell surface (27-29). It is our hypothesis that these phenomena contribute to the ability of breast carcinoma cells to detach from the original tumor and invade the adjacent tissues.

BODY

We have focused on establishing a transgenic mouse model system in which to investigate the role of integrin defects in breast cancer progression. To this end, we have examined transgenic mice carrying either an activated or a normal form of the N-*ras* oncogene under the control of the Mammary Tumor Virus Long Terminal Repeat (MMTV-LTR) promoter. These mice, similarly to mice carrying activated forms of the H-*ras* or *neu* oncogenes, develop mammary carcinomas with a high frequency during the first few months of their life (30-32; R. Mangues & A. Pellicer, Department of Pathology, N.Y.U. School of Medicine, unpublished results). The tumors which develop often consist of areas of different level of histological differentiation and thus can provide an insight to the process of primary breast tumor progression.

A) Immunohistochemical Analysis of Integrin Expression in Normal Murine Breast Tissue and Breast Tumors from a Point-Mutated N-ras Transgenic Mouse Line.

Normal murine breast demonstrated laminin staining along the basement membranes of both inter- and intra-lobular ducts as well as those of alveoli. The α6, β4 and β1 subunits were found to colocalize with laminin at the basement membrane junction. The α3 subunit staining was predominant along the basement membrane of the ducts with less prominent alveolar basal staining. The α2 subunit staining was similar to that for α3 but less intense. There was no significant staining above background levels in the ducts for either α5 or αv. Discontinuous αv staining could be detected at the myoepithelial basement membrane.

Oncogenic ras murine breast tumors displayed a significant loss of laminin staining. The α6 and β4 subunits were over-expressed, but lacked polarization; some basal staining could be seen in better differentiated tumor areas. The β1

staining was similarly no longer polarized, but it was not upregulated. The α2 and α3 subunits were also diffusely expressed in the tumors with an apparent increased intensity of α2 staining. The α5 and αv subunits were not expressed in the tumors.

B) Effect of Ras on Integrin Expression in a Murine Breast Cell Line.

To determine if the changes in integrin expression *in vivo* were a direct result of ras or due to other genetic changes which occur during tumor progression, the effect of the expression of the N-ras oncogene on integrin expression in a normal murine breast cell line was investigated. The heterogeneous murine breast cell line NMuNg was dilutionally cloned to isolate an epithelial cell line with an integrin repertoire similar to that of normal breast epithelium. The dilutional clone was stably transfected with a cDNA encoding the N-ras oncogene and the neomycin resistance selection marker. Control cell lines were transfected with the neomycin resistance gene only. Positive clones expressing high levels of N-ras were selected after soft agar subcloning.

Cell surface labeling and immunoprecipitation analysis indicated that the breast epithelial cell lines acutely transformed by N-ras expressed an integrin repertoire indistinguishable from that of control untransformed cell lines. Moreover the level of expression of individual integrin subunits in N-ras expressing cell lines was unchanged as compared to the controls.

C) Effect of Epidermal Growth Factor on the intercellular functions of α6β4 integrin.

Prompted by the prominent role of EGF and TGF-α in controlling epithelial cell growth and migration and by the coincident expression of α6β4 and EGF-R in many epithelial tissues including the breast epithelium, we have examined the effect of EGF-R activation on the intracellular functions of α6β4. Experiments of immunoblotting with anti-phosphotyrosine (anti-P-Tyr) antibodies and immunoprecipitation followed by phosphoamino acid analysis and phosphopeptide mapping showed that activation of the EGF-R causes phosphorylation of the β4 subunit at multiple tyrosine residues. Interestingly, immunoprecipitation experiments indicated that stimulation with EGF does not result in association of α6β4 with Shc. In contrast, EGF can partially suppress the recruitment of Shc to ligated α6β4. Furthermore, immunofluorescent analysis revealed that EGF treatment does not induce increased assembly of hemidesmosomes, but instead causes a deterioration of these adhesive structures without affecting initial adhesion to laminins. Finally, Boyden chamber assays indicated that exposure to EGF results in upregulation of α6β4-mediated cell migration toward laminins. Taken together, these results indicate that EGF-dependent signals have a complex effect on α6β4 function: they cause tyrosine phosphorylation of β4 without promoting the association of Shc, induce disassembly of hemidesmosomes, and upregulate cell migration on laminins (33). It is possible that the ability of activated EGF-R to coordinately disassemble

hemidesmosomes and upregulate α6β4-dependent cell migration play a role during tumor progression. It will be o

Since the consequences of EGF-mediated and ligand-induced tyrosine phosphorylation of β4 are distinct, it is likely that the activation of EGF-R and ligation of α6β4 cause phosphorylation of distinct sites in the β4 tail. Although we cannot formally exclude that the EGF-mediated and ligand-induced phosphorylation of β4 are mediated by a single tyrosine kinase differentially regulated by the two stimuli, it is more likely that they are mediated by two distinct tyrosine kinases. Since the immunopurified EGF-R does not efficiently phosphorylate β_4 *in vitro*, it is our hypothesis that the EGF-R does not directly phosphorylate β_4 *in vivo* but rather activates a signaling pathway that results in its phosphorylation. To identify tyrosine kinases capable of phosphorylating α6β4, we have performed immune-complex kinase assays in 293-T cells transiently transfected with β4 and overexpressing each one of various tyrosine kinases. The results demonstrated that the src-family kinase fyn can associate with α6β4 and phosphorylate the β4 tail in the absence of EGF stimulation. In contrast, src, lck, and jak-1 did not combine with and phosphorylate α6β4. This observation suggests that upon overexpression fyn can combine with α6β4 and phosphorylate the β4 tail. Since coimmunoprecipitation experiments indicated that α6β4 is not constitutively associated with endogenous fyn in A431 cells, HaCat keratinocytes, and 293 T cells stably transfected with β4 cDNA, we wondered if fyn played a role in EGF-induced phosphorylation of β4 and associated with α6β4 only in response to EGF treatment. The results indicated that, upon treatment with EGF, α6β4 forms a complex with both the activated EGF-R and endogenous fyn in A431 cells, HaCat keratinocytes, and 293 T cells stably transfected with β4 cDNA. In contrast, various β1 integrins did not form a complex with the activated EGF-R and fyn. These results suggest that the activated EGF-R may recruit fyn to the plasma membrane, thereby facilitating its interaction with α6β4. In accordance with this hypothesis, we have observed that increasing amounts of dominant negative (kinase-dead) fyn suppress the phosphorylation of β4 induced by EGF. Since the phosphorylation of β4 induced by EGF has a negative effect on hemidesmosome assembly, we have tested the effect of dominant negative fyn on hemidesmosome assembly. Interestingly, expression of dominant negative fyn led to increased assembly of hemidesmosomes in rat 804G cells. These results are consistent with the hypothesis that fyn is the tyrosine kinase which downregulates the intracellular functions of α6β4 in response to EGF stimulation.

The observation that the EGF-R and its close relative Erb2/neu are frequently overexpressed in squamous carcinomas raises the possibility that either the EGF-R or Erb2/neu or both affect the association of α6β4 with the hemidesmosomal cytoskeleton in breast cancer cells and these events may contribute to tumor invasion. In order to examine this hypothesis, we will compare the ability of breast cell lines expressing different levels of EGF-R or Erb2/neu to invade through matrigel in a Boyden chamber assay. If we find a correlation between increased expression of the EGF-R or Erb2/neu and invasive

ability *in vitro*, we will perform tumorigenicity assays in nude mice. Finally, we will introduce dominant negative fyn in at least three distinct cell lines overexpressing the EGF-R or Erb2/neu to examine if it suppresses the invasive ability of these cells, both *in vitro* and *in vivo*. As a control, the cells will be transfected with vectors encoding kinase-dead versions of fyn carrying a second mutation which inactivates its interaction with the growth factor receptor or α6β4. These experiments should help to understand if the interaction of EGF-R family members with α6β4 mediated by fyn plays a role in tumor invasion.

CONCLUSIONS

The above described studies indicate that the expression, and possibly the function, of several integrins involved in adhesion to the basement membrane is altered during the *in vivo* progression of breast cancer in the N-ras trangenic mouse model. The α6β4 and, to a minor extent, the α2β1 integrin are upregulated and diffusely distributed at the tumor cell surface in the primary lesions. These events are accompanied by a loss of laminin staining indicative of defective basement membrane deposition. The α3β1 integrin is diffusely distributed, but not upregulated. Since transfection of N-ras into cultured murine breast epithelial cells does not produce the changes in integrin expression detected *in vivo*, it is likely that these changes occur as a result of tumor progression independently of a direct action of N-ras. We have also discovered that the activated EGF-R combines sequentially with fyn and α6β4, leading to disassembly of hemidesmosomes and increased migratory activity. Future experiments will be addressed at determining if the EGF-R family member Erb2, which is often mutated and overexpressed in breast cancer, also combines with α6β4 and if this event contributes to breast cancer progression.

REFERENCES

1) Wellings, S.R., H.M. Jensen, and R.G. Marcum. 1975. An atlas of subgross pathology of the human breast with special reference to possible precancerous lesions. J. Natl. Cancer Inst. 55:231-273.

2) Dairkee, S.H., C. Blayney, H.S. Smith, and A.J. Ackett. 1985. Monoclonal antibody that defines human myoepithelium. Proc. Natl. Acad. Sci. U.S.A. 82:7409-7413.

3) Rudland, P.S.. 1987. Stem cells and development of mammary cancers in experimental rats and in humans. Cancer Metastasis Rev. 6:55-83.

4) Streuli, C.H., N. Bailey, and M.J. Bissell. 1991. Control of mammary epithelial differentiation: basement membrane induced tissue-specific gene expression in the absence of cell-cell interaction and morphological polarity. J. Cell Biol. 115:1383-1395.

5) Dulbecco, R., B. Armstrong, and R. Allen. 1988. Reversion toward an earlier stage of differentiation and loss of polarity during progression of N-methyl-N-nitrosourea induced rat mammary tumors. Proc. Natl. Acad. Sci. U.S.A. 85:9292-9296.

6) Petersen, O.W., L. Ronnov-Jessen, A.R. Howlett, and M.J. Bissell. 1992. Interaction with basement membrane serves to rapidly distinguish growth and differentiation pattern of normal and malignant human breast epithelial cells. Proc. Natl. Acad. Sci. U.S.A. 89:9064-9068.
7) Trask, D.K., V. Band, D.A. Zajchowski, P. Yawsen, T. Suh, and R. Sager. 1990. Keratins as markers that distinguish normal and tumor-derived mammary epithelial cells. Proc. Natl. Acad. Sci. U.S.A. 87:2319-2323.
8) Hynes, R.O..1992. Integrins: versatility, modulation, and signaling in cell adhesion. Cell 69:11-25.
9) Juliano, R.L., and S. Haskill. 1993. Signal transduction from the extracellular matrix. J. Cell Biol. 120:577-585.
10) Giancotti, F.G., and E. Ruoslahti. 1990. Elevated levels of the $\alpha_5\beta_1$ fibronectin receptor suppress the transformed phenotype of Chinese hamster ovary cells. Cell 60:849-859.
11) Burridge, K., K. Fath, T. Kelly, G. Nuckolls, and C. Turner. 1988. Focal adhesions: transmembrane junctions between the extracellular matrix and the cytoskeleton. Ann. Rev. Cell. Biol. 4: 487-525.
12) Mainiero, F., A. Pepe, L. Spinardi, K. Wary, M. Ammad, J. Schlessinger, J., and F.G. Giancotti. 1995. Signal transduction by the $\alpha_6\beta_4$ integrin: distinct β_4 sites mediate recruitment of Shc/Grb2 and association with the cytoskeleton of hemidesmosomes. E.M.B.O. J. 14: 4470-4481.
13) Wary, K.K., F. Mainiero, S. Isakoff, E.E. Marcantonio, and F.G. Giancotti. 1996. The adaptor protein Shc couples a class of integrins to the control of cell cycle progression. Cell 87: 733-743.
14) Burridge, K., L.A. Petch, and L.H. Romer. 1992. Signals from focal adhesions. Current Biol. 10:537-539.
15) Ruoslahti, E., and F.G. Giancotti. 1989. Integrins in tumor dissemination. Cancer Cells 1:119-126.
16) Ruoslahti, E.. 1984. Fibronectin in cell adhesion and invasion. Cancer Metastasis Rev. 3:34-51.
17) Hayman, E.G., E. Engvall, and E. Ruoslahti. 1981. Concomitant loss of fibronectin and laminin from transformed rat kidney cells. J. Cell Biol. 88:352-357.
18) Chen, W.T., E. Hasegawa, T. Hasegawa, C. Weinstock, and K.M. Yamada. 1985. Development of cell surface linkage complexes in cultured fibroblasts. J. Cell Biol. 100: 1103-1114.
19) Damsky, C.H., K.A. Knudsen, D. Bradley, C.A. Buck, and A.F. Horowitz. 1985. Distribution of the cell substratum attachement (CSAT) antigen on myogenic and fibroblastic cells in culture. J. Cell Biol. 100: 1528-1539.
20) Giancotti, F.G., P.M. Comoglio, and G. Tarone. 1986. A 135,000 molecular weight plasma membrane glycoprotein involved in fibronectin-mediated cell adhesion. Immunofluorescence localization in normal and RSV-transformed fibroblasts. Exp. Cell Res. 163:47-62.
21) Chen, W.-T., J. Wang, T. Hasegawa, S.S. Yamada, and K.M. Yamada. 1986. Regulation of fibronectin receptor distribution by transformation, exogenous fibronectin, and synthetic peptides. J. Cell Biol. 103:1649-1661.

22) Hirst, R., A.F. Horwitz, C.A. Buck, and L. Rohrschneider. 1986. Phosphorylation of the fibronectrin receptor complex in cells transformed by oncogenes that encode tyrosine kinases. Proc. Natl. Acad. Sci. U.S.A. 83:6470-6474.
23) Tapley, P., A.F. Horwitz, C.A. Buck, K. Duggan, and L. Rohrschneider. 1989. Integrins isolated from RSV-transformed chicken embryo fibroblasts. Oncogene 4:325-333.
24) Plantefaber, L.C., and R.O. Hynes. 1989. Changes in integrin receptors on oncogenically transformed cells. Cell 56:281-290.
25) Symington, B.E.. 1990. Fibronectin receptor overexpression and loss of transformed phenotype in a stable variant of the K562 cell line. Cell Regul. 1:637-648.
26) Schreiner, C.L., M. Fisher, S. Hussein, and R.L. Juliano. 1991. Increased tumorigenicity of fibronectin receptor deficient Chinese hamster ovary cell variants. Cancer Res. 51:1738-1740.
27) Zutter, M.M., G. Mazoujian, and S.A. Santoro. 1990. Decreased expression of integrin adhesive protein receptors in adhenocarcinoma of the breast. Am. J. Pathol. 137:863-870.
28) Koukoulis, G.K., E. Virtanen, M. Korhonen, L. Laitinen, V. Quaranta, and V.E. Gould. 1991. Immunohistochemical localization of integrins in the normal, hyperplastic, and neoplastic breast. Am. J. Pathol. 139:787-799.
29) Natali, P.G., M.R. Nicotra, C. Botti, M. Mottolese, A. Bigotti, and O. Segatto. 1992. Changes in expression of $\alpha_6\beta_4$ integrin heterodimer in primary and metastatic brest cancer. Br. J. Cancer 66:318-322.
30) Mangues, R., E. Seidman, G.W. Gordon, and A. Pellicer. 1992. Over-expression of the N-*ras* protooncogene, not somatic mutational activation associated with malignant tumors in transgenic mice. Oncogene 7:2073-2076.
31) Sinn, E., W.J. Muller, P.K. Pattengale, I. Tepler, R. Wallace, and P. Leder. 1987. Coexpression of MMTV/v-H-*ras* and MMTV/c-*myc* genes in transgenic mice: synergistic action of oncogenes *in vivo*. Cell 49:465-475.
32) Muller, W.J., E. Sinn, P.K. Pattengale, R. Wallace, and P. Leder. 1988. Single-step induction of mammary adenocarcinoma in transgenic mice bearing the activayed c-*neu* oncogene. Cell 54:105-115.
33) Mainiero, F., A. Pepe, M. Yeon, Y-L. Ren, and F.G. Giancotti. 1996). The intracellular functions of $\alpha_6\beta_4$ integrin are regulated by EGF. J. Cell Biol. 134: 241-253.